Competency 1.11 **Industrial hygiene personnel shall demonstrate a working level knowledge of the design of engineering measures to control exposure.**

1. Supporting Knowledge and Skills

a. Discuss basic design principles for heating, ventilation, and air conditioning (HVAC) systems including the following:
   - Local exhaust ventilation
   - Dilution ventilation
   - Air recirculation
   - Make-up air supply
   - Energy balances

b. Describe the design principles and performance of air cleaners and explain the roles they play in minimizing worker exposure to chemicals and biological hazards.

c. Discuss the major regulations and standards governing ventilation systems.

d. Describe the following environmental factors:
   - Atmospheric dispersion modeling
   - Control of hypo- and hyper-baric conditions
   - Psychrometry

e. Discuss the principles of isolation and enclosure as they relate to the following:
   - Noise
   - Air contaminants
   - Radiation
   - Hazardous waste

f. Discuss the economic feasibility of the following:
   - Engineering Controls (including process change and substitution)
   - Administrative Controls
   - Personnel protective equipment (PPE)

g. Discuss the basic design principles used to control vibration and noise.

h. Describe the engineering principles used in controlling the following forms of radiation:
   - Non-ionizing
   - Ionizing

i. Discuss the control of flammable and combustible gases and vapors.

j. Discuss the means by which ergonomic stressors are controlled.

k. Describe how to evaluate the effectiveness of engineering measures used to control biological hazards.

l. Discuss the engineering measures used to control heat stress.

m. Describe the control features (backflow prevention, etc.) of potable water supply distribution.

n. Discuss the importance of engineering controls as they relate to sanitation of food service facilities and equipment.

2. Recommended Reading

Review

- 29 CFR 1910, Subpart J, "General Environmental Controls."
- *Fundamentals of Industrial Hygiene*, 3rd Edition or later edition, National Safety Council, Chapters 20, 21, and 22.
- Patty's *Industrial Hygiene and Toxicology*, Volume I, 4th Edition, Chapters 22, "Air Pollution Controls," and 27, "Industrial Hygiene Engineering Controls."
- *Noise Control, A Guide for Workers and Employees*, U.S. Department of Labor, Occupational Safety and Health Administration.
- *Industrial Ventilation*, American Conference of Governmental Industrial Hygienists.

3. Summary

Regulations, technical guidance, and good practices emphasize the implementation of engineering controls where feasible. Administrative controls are viewed less favorably, but are generally considered acceptable. Reliance on personal protective equipment, because of its reliance upon individual employee knowledge and other human variables, is regarded as the least desirable overall.

The most common form of engineering control is ventilation of the work place.

The industrial hygienist must be familiar with the components of the facility's ventilation systems and the methods used to control both industrial sources of contaminants and indoor air contaminants. The industrial hygienist should also have a grasp of the state-of-the-art control technologies and methods used to evaluate control system performance.

Adequate ventilation is best achieved where the plant engineer, management, workers, and the industrial hygienist work together. Frequently, older facilities and their ventilation systems were designed for production purposes with little thought given to health considerations. Retrofit or redesign is sometimes required to meet today's standards.

Local exhaust is most often the control technology of choice in that its components remove contaminants at their source. Dilution is sometimes used, but is less effective in that contaminants remain (although less concentrated). Air recirculation may be used to conserve energy where air contaminants are of a low toxicity and concentration. Makeup air plays a key role in the HVAC process to introduce "fresh" air to the building and to replenish exhausted air. "Balanced" systems provide a good proportional flow of air to all areas, and also ensure that the HVAC system is at equilibrium between incoming and outgoing air. However, in some institutional or industrial situations, a "negative" or "positive" flow may be desirable in order to maintain parts of the building at positive or negative pressure.

Air cleaners are typically categorized as one of two types. The first is one used to remove industrial type pollutants—dusts, mists, fumes, vapors, and biologicals from the immediate and surrounding areas. Devices such as precipitators, centrifuges, scrubbers, and fabric and high-efficiency particulate air (HEPA) filters are commonly used in these applications. The second type of air cleaners are those that are used in recirculating HVAC systems as in-line devices to reduce low level or toxic contaminants. These include fiber filters or electrostatic precipitators.

Legal requirements for ventilation systems are addressed in 29 CFR 1910.94. These requirements are, however, antiquated and limited to a few industrial situations, and are not generally useful. 29 CFR 1910.19 makes reference to specific air contaminants as "special provisions." These include substances such as lead, vinyl chloride, ethylene oxide, and others of a high-hazard nature.

Recognized consensus standards play a key role in ventilation practices. Standards published by the American National Standards Institute (ANSI), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the American Industrial Hygiene Association (AIHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) are at the forefront of these documents. Of significance in the control of indoor air quality is ANSI/ASHRAE 62-1989, "Ventilation for Acceptable Air Quality."

Atmospheric dispersion modeling refers to the process of simulating an environmental release and estimating the resultant impact on a geographic area as affected by a number of variables including the characteristics of the source, local weather, topography, and toxicity. Most frequently this is achieved using computer programs and entering the available data.

Hyper- and hypo-baric environments are sometimes advantageous for biomedical, biophysical and physical chemistry research and therapy. The use of pressurized or depressurized chambers presents unusual conditions and challenges for the industrial hygienist, including gas solubility, vapor pressures, and density properties, which may increase the dose to employees, affect engineering controls, and influence sampling results.

Psychrometry refers to the measurement of the relative humidity of air using wet-bulb and dry-bulb thermometers.

Isolation and enclosure are two important controls available to the industrial hygienist. Isolation means restricting access to an operation so that only a few designated employees are potentially exposed. Enclosure means placing the operation in a physical enclosure (e.g., a glove box) to prevent release of contaminants. Isolation is intended to prevent unnecessary exposure to the public or workers not performing the local operation; enclosure, on the other hand, is intended to contain the agent or contaminant and prevent exposure to all workers. Isolation can be used when few workers are involved or when operations are difficult to accomplish within enclosures, e.g., as is often the case with hazardous wastes. Sometimes isolation in conjunction with enclosure can be very effective. For example, this is the case for certain operations involving highly toxic beryllium powder that cannot be accomplished in a total enclosure. Noise can be reduced using both principles dependent on the source and the conditions. The isolating barrier around a noisy machine and operations will prevent unnecessary noise to the rest of the workplace and public. Enclosures around an especially noisy piece of machinery would reduce exposure even for the workers in the immediate proximity of the machine.

Although not really an engineering control, material substitution, i.e., the replacement of a hazardous material with another material having less hazardous qualities, is considered comparable in effectiveness. Material substitution may be considered especially appropriate for the control of exposure to carcinogenic agents.

Engineering controls are preferred because they are considered more permanent and do not rely upon the performance of the individual worker. However, these controls usually require a high initial investment in planning and implementation. Payback is in the form of reduced exposure, increased productivity, and enhanced worker health. Administrative controls are usually less costly, but are less dependable. They have a high degree of risk because of human error or procedural noncompliance. Personal Protective Equipment (PPE) is an important part of the overall safety and health program; however, it should not be relied upon exclusively. PPE is less costly than engineering controls, but many variables can reduce the actual protection afforded, and using PPE creates some new risks. The use of PPE has high administrative cost and PPE may also be relatively costly as in the case of hazard-specific gloves or respirators, and replacement of contaminated or worn out PPE.

Noise and vibration control can be effectively achieved by several design techniques. These include source control (reducing speed, dampening, bracing, etc.), enclosure, isolation, insulation, shielding, distance, and baffling. Each of these or various combinations can be used depending on the particular situation and the economic support for the project.

Engineering controls for ionizing radiation is primarily a function of shielding. Appropriate shielding thickness, material, density, and configuration specific to alpha, beta, gamma (and x-ray), and neutron radiation is dependent on the source material and its energy. Other engineering controls including distance and the use of locking devices may be appropriate to the application. Nonionizing radiation requires engineering controls that are highly dependent on the use and conditions. Locking mechanisms to control access and use, and limitation of range of lateral movement of the source, distance, shielding, and enclosure can all be used for engineering controls.

Gases and vapors can be significant flammable hazards. Adequate controls of these substances take several forms including the use of appropriate storage containers, segregation, temperature controls, ventilation of storage areas, detection and suppression systems, regulators, and spark-suppressing tools. Administrative controls, including adherence to policies and procedures, controlled access, and restricted use of materials, are also highly important.

4. Suggested Exercises

Please refer to Scenarios 2 and 10 in the Scenario section of this document.